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PSYCHOSIS (A AHMED, SECTION EDITOR)

A Review of Anticipatory Pleasure in Schizophrenia

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Abstract
Purpose of Review Anhedonia, traditionally defined as a diminished capacity to experience pleasure, has long been considered a core symptom of schizophrenia. However, recent research calls into question whether individuals with schizophrenia are truly anhedonic, suggesting intact subjective and neurophysiological response to rewarding stimuli in-the-moment. Despite a presumably intact capacity to experience pleasure, people with schizophrenia still engage in fewer reward-seeking behaviors. This discrepancy has been explained as a dissociation between "liking" and "wanting," with dopaminergic and prefrontal influences on incentive salience leading hedonic responses to not effectively translate into motivated behavior. In the current review, the literature on a key aspect of the wanting deficit is reviewed, anticipatory pleasure.
Recent Findings Results provide consistent evidence for impairment in some aspects of anticipatory pleasure (e.g., prospection, associative learning between reward predictive cues and outcomes) and inconsistent evidence for others (e.g., anticipatory affect and affective forecasting).
Summary Mechanisms underlying anticipatory pleasure abnormalities in schizophrenia are discussed, and a new model of anticipatory pleasure deficits is proposed. Findings suggest that anticipatory pleasure may be a critical component of impairments in wanting that impact motivated behavior in schizophrenia.

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Introduction

Anhedonia, traditionally defined as a diminished capacity to experience pleasure, has long been considered a core clinical feature of schizophrenia [1, 2]. However, modern empirical investigation calls into question whether this original definition accurately applies to individuals with schizophrenia [3, 4]. Specifically, in laboratory-based studies, individuals with schizophrenia report levels of positive emotion [5••] and arousal [6] that are equivalent to controls when exposed to pleasant stimuli and show a similar magnitude of neurophysiological response when directly viewing pleasant stimuli [7, 8•]. Ecological momentary assessment studies also indicate that individuals with schizophrenia report comparable levels of in-the-moment positive emotion to controls when engaged in goal-directed activities in everyday life [9, 10•, 11]. Such findings have led some to conclude that hedonic capacity may be surprisingly intact in schizophrenia [12••, 13]. However, not all aspects of emotion appear fully normal in schizophrenia. For example, studies using ecological momentary assessment and clinical interviews of negative symptoms also indicate that the majority of people with schizophrenia engage in fewer pleasurable activities than controls [12••, 14], despite enjoying these activities when engaged in them [9, 10•, 11]. Thus, anhedonia may be more accurately understood as a reduction in the frequency of pleasurable activity than the capacity to experience pleasure in schizophrenia.

Recent attempts to explain this dissociation between reduced pleasurable activity and intact hedonic capacity have drawn upon conceptual frameworks from the field of neuroscience that posit separate neural systems for "liking" versus

"wanting" [15]. These theories propose that dopamine is critical for wanting, but not liking, playing a role in how incentive salience is signaled and how appetitive behavior is initiated. Disruptions in tonic and phasic dopamine may contribute to impaired wanting in schizophrenia, impacting cortico-striatal interactions and a host of reward-related processes involved with translating hedonic response into motivated behavior (e.g., value representation, effort-cost computation, action selection, reinforcement learning) (for reviews, see [16, 17]). One of the most critical processes involved with wanting is "anticipatory pleasure," which involves several processes, including the following: (1) associative conditioning: the ability to acquire associations between originally neutral cues and reward outcomes; (2) prospection: the ability to generate mental simulations of the future, often by drawing upon memories from the past; (3) anticipatory affect: the ability to experience positive emotion in-the-moment while simulating the future; and (4) affective forecasting: predicting how good we will feel when an event occurs. These anticipatory pleasure constructs are starting to receive considerable attention in the field of schizophrenia research. The current manuscript reviews this literature to date, synthesizes findings, and draws upon basic neuroscience and affective science to understand mechanisms that may underlie deficits in wanting.

Associative Conditioning: Neural Response to Reward Predictive Cues

The ability to form associations between cues predicting potential rewards or losses and outcomes themselves plays an important role in influencing approach or avoidance behaviors [18]. Basic neuroscience models of learning have demonstrated dissociations between neural activity that occurs in response to outcomes versus the neural response to cues preceding those outcomes [19–21]. Specifically, there is greater nucleus accumbens activation to reward predictive cues than the receipt of reward outcomes, whereas reward outcomes activate the medial prefrontal cortex (MPFC) to a greater extent than reward predictive cues. Reward outcomes also activate the MPFC to a greater extent than loss outcomes. Similar increases in activation are not observed in the nucleus accumbens and MPFC during loss anticipation or outcomes; however, there is increased activation of the anterior insula for anticipated losses relative to anticipated rewards [18, 20].

Neural distinctions between anticipation and outcome processing have primarily been measured using the Monetary Incentive Delay (MID) task. The MID is designed to isolate the neural response to value predictive cues from valued outcomes through the manipulation of certainty, probability, and magnitude of reward and loss ([22]: for variants, see [23–25]). In a typical MID trial, a cue is first presented indicating availability of a potential monetary reward, potential monetary loss, or neutral outcome (no monetary win or loss). After the cue, participants experience a brief delay, followed by the rapid presentation of a target (e.g., shape) to which they are directed to respond as quickly as possible. To achieve a "hit," or a successful trial, participants have to respond to the target while it is still on the screen. Failing to press the button in time results in a "miss" or unsuccessful trial. Directly following target presentation, participants are given feedback as to whether they won, lost, or avoided losing monetary rewards [22].

To date, 23 functional neuroimaging studies have administered variants of the MID to individuals with schizophrenia. Generally, studies indicate that individuals with schizophrenia display attenuated activation in the ventral striatum (VS) to anticipatory reward cues [26–29, 30••, 31–36], although some studies find no differences between controls and schizophrenia patients in VS activation [37, 38•, 39–42]. Inconsistent findings may be partially explained by antipsychotics, as there is some evidence that second-generation antipsychotics have a normalizing effect on the VS in response to reward predictive cues [27, 31, 30]. Inconsistent results may also reflect symptom heterogeneity, as reduced activation of the VS is often associated with greater severity of negative symptoms, even in studies that do not find group differences [26, 27, 31, 41-43, 24, 36, 38]. Neural response to cues predicting potential losses appears comparable in schizophrenia patients and controls, with both groups activating the VS ([32, 34, 35, 39]; however, see [27, 30, 33]). With regard to neural response to reward outcomes, the majority of studies indicate no differences between individuals with schizophrenia and control subjects in VS, MPFC, and medial orbital frontal cortex (mOFC) [40, 41, 37, 39, 38]; however, some studies have reported that schizophrenia patients have reduced activation in the MPFC, VS, ventral prefrontal cortex, prefrontal cortex, and lateral temporal cortex [32, 44, 42, 29, 38]. Few studies have analyzed the neural response to loss outcomes specifically, with some evidence for comparable activation of the VS in schizophrenia patients and controls, but no reports of MPFC, OFC, or anterior insula differences [39]. The lack of studies specifically examining loss outcomes reflects the primary use of the loss condition for calculating difference scores to isolate the activation difference between losses and gains. However, as demonstrated by a meta-analysis of fMRI studies of the amygdala, reliance on difference scores comes with the disadvantage of masking condition-related differences [43]. It is possible that inconsistent findings may reflect the use of difference scores, which obscure whether activation differences reflect decreased response to reward outcomes/cues or increased response to loss outcomes/cues.

Similar patterns of VS hypoactivation in the reward anticipation condition can be seen in individuals at clinical high risk for developing schizophrenia, who also display hypoactivation in the insula, parietal cingulate cortex, supplementary motor area, and medial frontal gyrus [24, 44, 45];

however, results are inconsistent, and some studies show no differences in VS activation in response to expectation of rewards [45–47]. Responses during loss anticipation also show VS hypoactivation [29, 44, 47]. Outcome responses were not examined in these studies. Inconsistent findings may reflect symptom heterogeneity and differences in the relative proportion of participants that will eventually convert to a psychotic disorder in each study.

In addition to the MID, reward anticipation has been examined through other paradigms, with similar results. One study using a Pavlovian reward prediction task found greater ventromedial prefrontal cortex, cerebellum, and left posterior cingulate activation to reward cues in controls than in individuals with schizophrenia, and also found that lower VS and ventromedial prefrontal cortex activation during the reward cue phase were associated with greater severity of anhedonia [43]. A similar Pavlovian conditioning study presented participants with red and black circles associated with differential amounts of reward as well as a star signaling no reward [48]. This study determined that the effective connectivity from the VS to the hippocampus is greater in individuals with schizophrenia than controls for CS- (neutral) stimuli relative to rewarding stimuli [48]. Another study examining adaptive salience (with regard to uncertain reward/loss over certain neutral and high probability of reward vs low probability of reward) indicated that first-episode patients showed attenuated response to high-probability rewarding cues in the left dorsal cingulate gyrus, the right insula, and the anterior cingulate gyrus (as compared to prodromal subjects) [49]. One study using ERP examined reward anticipation in individuals with schizophrenia through analysis of the contingent negative variation (CNV) and the stimulus preceding negativity (SPN) ERP components, which are involved in anticipatory processes, in response to a cued picture viewing task [50••]. Participants were shown a cue indicating that the following image would be positive, negative, or neutral. An image was presented after a time delay. Results indicated that individuals with schizophrenia display diminished CNV and SPN as compared to controls in response to prediction of emotional experience associated with viewing neutral and affective stimuli [51].

Collectively, these findings suggest a potential dissociation between the neural response to rewards and punishments in schizophrenia that interacts with cue versus outcome processing. The neural response to rewarding outcomes appears to be intact, as most studies show no significant differences between controls and individuals with schizophrenia with regard to intact MPFC, OFC, ACC, and VS responsiveness to reward. Studies have not examined loss outcomes in isolation enough to determine whether these are intact. As one study found increased MPFC activation in individuals with schizophrenia in response to loss compared to controls, more research into loss responding may be warranted [32]. Taken together, these results indicate that while the neural response to reward predictive cues may be blunted in individuals with schizophrenia, the neural response to cues predicting negative outcomes may be intact (see Table 1). Furthermore, negative symptom severity appears to predict the magnitude of VS hypoactivation; however, second generation antipsychotics may help to normalize the blunted response.

Anticipatory Affect, Affective Forecasting, and Prospection:

The human brain is constantly combining newly acquired information from the external world with information already stored in semantic or episodic memory to form or update "mental representations" (i.e., internal models of the world). Mental representations come in three forms: simulations (i.e., representations of future events), perceptions (i.e., representations of current events), and memories (i.e., representations of past events). The ability to simulate future events in a way that induces positive emotion in-the-moment (i.e., anticipatory affect) and allows us to predict our hedonic reactions to future events (i.e., affective forecasting) is critical to survival, facilitating decisions to engage in appetitive or avoidance behavior [52].

Early research suggested that simulating future events (i.e., prospection) relies heavily on the prefrontal cortex [53–55] and that neurological patients with damage to the prefrontal cortex have deficits in prospection [56]. More recently, studies have demonstrated that these prefrontal deficits may be better explained by circuit-level dysfunction in the default mode network (DMN). The DMN consists of anatomically interconnected and interacting brain regions, including the ventromedial prefrontal cortex, posterior cingulate cortex, precuneus, retrosplenial cortex, inferior parietal lobule, lateral temporal cortex, dorsal MPFC, and hippocampal formation [57]. It is activated when individuals are not directly engaged in tasks and allowed to let their minds wander. In such instances, the default state is to generate simulations of the future or recall episodes from the past. Numerous studies indicate that individuals with schizophrenia have structural and functional abnormalities of the prefrontal cortex [8•, 58] and abnormal activation of the DMN [59–62]. Although abnormalities in the prefrontal cortex and DMN could be expected to contribute to problems with multiple aspects of anticipatory pleasure in schizophrenia, this possibility has yet to be empirically tested.

Few studies have evaluated anticipatory affect, affective forecasting, or prospection in schizophrenia. Studies conducted to date have utilized three methods: ecological momentary assessment (EMA), laboratory-based task self-report, and self-report questionnaires. The first study in this area was conducted by Gard et al. [9], and it used two of these methods, EMA and self-report questionnaires. The study had two phases. In

Table 1 Summary of neuroimaging studies measuring associative conditioning

Citation	Participants	Measure	Reward anticipation	Loss anticipation	Outcome gain	Outcome loss	Symptom correlations
Juckel et al., 2006a [27]	20 SZ (10 1st gen AP, 10 2nd gen AP), 10 CN	MID	SZ treated with 2nd gen AP VS = CN; SZ treated with 1st gen AP VS < CN	NR	NR	NR	SZ treated with first-generation antipsychotics: greater negative symptom severity associated with lower VS activation
Juckel et al., 2006b [26]	10 SZ (unmedicated), 10 CN	MID	SZ VS < CN	SZ VS < CN	NR	NR	Reduced VS activation correlated with increased negative symptom severity
Abler et al., 2008 [40]	12 SZ,12 BP, 12, CN	Modified MID	SZ VS = CN	NR	SZ VS = CN	NR	None
Schlagenhauf et al., 2008 [31]	10 SZ, 10 CN	MID	Baseline: SZ VS < CN Post switch to 2nd gen: SZ VS = CN	Baseline: SZ VS < CN Post switch to 2nd gen: SZ VS = CN	NR	NR	Reduced left VS activity correlated with higher negative symptoms at baseline
Schlagenhauf et al., 2009 [32]	15 SZ and 15 CN	MID	SZ VS < CN	SZ VS = CN	SZ MPFC < CN for reward, SZ VS < CN for loss avoidance	SZ = CN	Greater severity of positive symptoms associated with reduced MPFC activation for outcome loss-avoidance response
Walter et al., 2009 [119]	16 SZ, 16 CN	Modified MID	SZ dACC < CN with reward increase	NR	SZ right VPFC < CN during high reward	NR	Reduced activation of dACC associated with increased disorganization
Simon et al., 2010 [41]	10 SZ, 12 CN	Modified MID	SZ VS = CN	NR	SZ mOFC, VS = CN	NR	Reductions in VS activation correlated with greater apathy during anticipation, activation during outcome correlated with depression severity
Waltz et al., 2010 [42]	17 SZ, 17 CN	Modified MID	SZ VS = CN	NR	SZ PFC, LTC and amygdala < CN (relative to losses)	NR	Greater social anhedonia correlated with greater VS activity; greater negative symptom ratings correlated with reduced MPFC activation to loss; greater negative symptom cluster BPRS and total SANS score associated with abberant inferior frontal gyrus actvation; total BPRS associated with lateral PFC activation
Esslinger et al., 2012 [28]	27 FEP, 27 CN	Modified MID	SZ VS < CN	NR	NR	NR	Greater PANSS-rated delusions, hostility, and better executive functioning associated with reduced VS activity
Juckel et al., 2012 [47]	13 HR, 13 CN	MID	HR VS = CN	HR VS < CN (trend)	NR	NR	None
Nielsen et al., 2012a [29]	31 SZ, 31 CN	Modified MID	SZ VS, VTeg, ACC < CN	SZ VS, VTeg, ACC < CN	SZ DLPFC < CN (trend)	NR	Elevated positive symptoms (PANSS) correlated with VS attenuation
Nielsen et al., 2012b [30••]	23 FEP SZ, 24 CN	Modified MID	Baseline SZ VS < CN, post-treatment SZ VS = CN	NR	NR	NR	Association between decrease in positive symptoms and increase in reward-related activation
da Silva Alves et al., 2013 [33]	10 SZ, 12 CN	MID	Experimental- SZ MFG and right IFG < CN. Placebo- SZ right STG and LPC < CN.	Experimental- SZ VS = CN Placebo- SZ STG, PCC, VS, CC, FCC < CN	NR	NR	None
Wotruba et al., 2014 [46]	21 HR, 24 CN	Modified MID	Increased activation in PCC, medial and	NR	HR = CN (mOFC, VS)	NR	Increased positive symptoms correlated with increased VS

Table 1 (continued)

Citation	Participants	Measure	Reward anticipation	Loss anticipation	Outcome gain	Outcome loss	Symptom correlations
			superior frontal gyrus in HR in anticipation.				and right IN activation, increased depression with mOFC at outcome, increased negative symptoms related to outcome-related VS hypoactivation
Grimm et al., 2014 [44]	54 HR, 80 CN	Modified MID	HR VS < CN	HR VS < CN	NR	NR	None
de Leeuw et al., 2015 [24]	27 HR, 28 CN	Modified MID	HR VS, IN, Supplementary motor area < CN	NR	HR VS and OFC > CN	NR	Attenuated VS associated with negative symptoms (subclinical)
Gilleen et al., 2015 [37]	20 SZ, 12 CN	MID	SZ = CN (inferior frontal/ superior frontal gyri, left pre-/postcentral gyri, VS, IN, medial/ cingulate gyri, thalamus, hippocampus, brainstem)	NR	SZ = CN (OCC, lingual gyrus, PCC, ACC)	NR	Attenuated dACC in anticipation and outcome associated with lower subjective wellbeing
Mucci et al., 2015 [39]	28 SZ, 22 CN	Modified MID	SZ VS = CN; Deficit SZ dcaudate < CN, non deficit SZ	SZ = CN (caudate, dlPFC, OFC, temporal pole, MTF, OCG, precuneus, cerebellum, SOG	SZ = CN (VS, mesial PFC, ACC, OFC, IN, cerebellum, post central gyrus, temporal pole)	SZ = CN	Greater avolition associated with attenuated dorsal caudate activation
Hanssen et al., 2015 [45]	94 HR, 57 CN	Modified MID	HR VS = CN; HR IN, PCC, MFG deactivation < CN	NR	HR precuneus, PCC, MFG deactivation < CN	NR	Greater MFG activity associated with greater negative symptoms
Subramaniam et al., 2015 [34]	37 SZ, 20 CN	MID	SZ VS < CN	SZ = CN (lingual, cuneus)	SZ = CN (mPFC, ACC, caudate/ putamen)	SZ mSFG < CN	Greater positive symptom severity correlated with mPFC and mid-cingulate activation
Hägele et al., 2015 [35]	26 alcohol dependent subjects, 44 SZ, 24 MDD, 13 BD, 23 ADHD, 54 CN	MID	SZ VS < CN	SZ VS = CN	NR	NR	Depression was associated with impaired reward anticipation (All groups)
Arrondo et al., 2015 [36]	22 SZ, 24 MDD, 21 CN	Modified MID	SZ VS < CN	NR	NR	NR	Attenuated VS activation associated with greater anhedonia and depression
Kirschner et al., 2016 [38•]	27 SZ, 25 CN	Modified MID	SZ VS = CN	NR	VS mOFC = CN; SZ right VS > CN	NR	Increased apathy associated with VS hypoactivation during anticipation

SZ schizophrenia, *CN* control, *AP* antipsychotic, *VS* ventral striatum, *NR* not reported, *BP* bipolar, *MPFC* medial prefrontal cortex, *DLPFC* dorsolateral prefrontal cortex, *dACC* dorsal anterior cingulate cortex, *VPFC* ventral prefrontal cortex, *PFC* prefrontal cortex, *LTC* lateral temporal cortex, *FEP* first-episode patients, *HR* high risk, *BPRS* Brief Psychiatric Rating Scale, *SANS* Scale for the Assessment of Negative Symptoms, *PANSS* Positive and Negative Syndrome Scale, *VTeg* ventral tegmentum, *STG* superior temporal gyrus, *PCC* posterior cingulate cortex, *IFG* inferior frontal gyrus, *MFG* medial frontal gyrus, *CC* cingulate cortex, *FCC* frontal cingulate cortex, *LPC* left posterior cingulate cortex, *dcaudate* dorsal caudate, *IN* insula, *mOFC* medial orbitofrontal cortex, *SOG* superior occipital gyrus, *OCG* occipital gyrus, *mSFG* medial superior frontal gyrus

the first phase, EMA, participants were paged 7 times per day for 1 week. Upon hearing the page, participants were directed to write down their activities and their current experience of pleasure, rating their enjoyment from 0 (not at all) to 5 (very much). Participants were also asked to rate what activities they were looking forward to, without a specified timeframe, and how much pleasure they expected to derive from the future activity on the same scale. Activities were selected from a list. Results indicated that individuals with schizophrenia reported as much positive emotion when engaged in activity as controls (i.e., consummatory pleasure), but lower levels of anticipatory pleasure when engaged in activities. In the second phase, participants completed the Temporal Experience of Pleasure Scale (TEPS: [63], which consists of 18 questions designed to measure both consummatory and anticipatory pleasure. Higher scores on the scales represent more pleasure (i.e., less anhedonia). Psychometrics indicate good internal consistency, convergent and discriminate validity, and test-retest reliability [63]. The TEPS results converged with their EMA data, indicating intact consummatory pleasure and reduced anticipatory pleasure in schizophrenia.

Subsequent studies have attempted to replicate the EMA findings of Gard et al. [9] with inconsistent results. In a more recent EMA study [10•], research assistants called participants 4 times per day for 7 days and asked them semi-structured questions about their activities, goals for the next few hours, and consummatory and anticipatory pleasure. During later calls, participants were asked if they completed the goals mentioned in the earlier calls. The results of this second EMA study were inconsistent with the results of Gard et al. [9]. Instead of reduced anticipatory pleasure and equivalent consummatory pleasure, individuals with schizophrenia reported significantly more anticipatory pleasure for goals than controls and reported similar consummatory pleasure. Another EMA study investigating anticipatory pleasure [64] began with a prospective anticipatory affect questionnaire completed in the laboratory. Participants were directed to predict how positive and negative they expected to feel over the coming week. Participants were then provided with a personal digital assistant (PDA) programmed with experience-sampling software. They were prompted to answer questions about their in-the-moment positive and negative feelings six times a day for a week. Results found that individuals with schizophrenia generally overestimate the amount of positive and negative emotion they would feel throughout the week. However, as this study contained a patient group without a control sample, conclusions cannot be drawn regarding whether deficits in anticipatory or consummatory pleasure occurred. Inconsistencies across studies may reflect an intact ability to experience pleasure during anticipation, not the ability to predict future pleasure. This may relate to deficits in the ability to form mental representations [65]. If this is accurate, individuals with schizophrenia may rely more on beliefs about future pleasure than the hedonic experience generated by the anticipated event itself to guide their prospective reports.

Similar to the EMA studies, studies using the TEPS conducted after Gard et al. [9] are also inconsistent. Of the 23 studies that included schizophrenia and control samples, 11 have found lower anticipatory pleasure in individuals with schizophrenia than controls [9, 51, 66–74]; however, these findings may be specific to patients with severe negative symptoms [75]. Ten studies found no group differences in anticipatory pleasure [39, 76–84]. Eight studies found lower consummatory pleasure in schizophrenia patients than controls [70, 71, 73, 74, 77, 80–82], while 12 found no group differences in consummatory pleasure [9, 39, 51, 66, 68, 69, 72, 76, 78, 79, 83, 84]. Eleven studies have reported group means for the TEPS subscales in patient and control groups, which provide evidence for numerically lower consummatory and anticipatory pleasure in schizophrenia: schizophrenia anticipatory = 4.17; control anticipatory = 4.54; schizophrenia consummatory = 3.99; control consummatory = 4.35. These findings suggest that a meta-analysis of TEPS studies would be beneficial. Table 2 contains a full list of studies examining differences in the TEPS between individuals with schizophrenia and controls.

Several factors may explain inconsistent TEPS findings. First, demographic differences, such as age, sex, and ethnicity, among samples may influence self-reports of both controls and patients. Age may be an important factor, as certain questions on the TEPS (e.g., “when I’m on my way to an amusement park, I can hardly wait to ride the roller coaster”) may be more applicable to younger samples than the more traditional middle-aged chronic schizophrenia sample. Indeed, heterogeneity among control, more so than patient samples, in TEPS anticipatory and consummatory scores may explain why some studies find group differences on each scale and others do not [85]. Second, there may be an under-recognized role of antipsychotics. First-generation antipsychotics can increase levels of anhedonia through dopamine antagonism. Given that dopamine is more closely linked to problems with wanting than liking [15], one might expect that studies with a higher proportion of patients on first-generation antipsychotics would be more likely to find an anticipatory pleasure deficit, and there is some evidence consistent with an effect of first-generation drugs. For example, in the original study by Gard et al. [9], which found an anticipatory pleasure deficit, 31 % of the patients were prescribed first-generation antipsychotics as compared to much lower percentages in studies not finding an anticipatory pleasure deficit (e.g., 12 % in [80]). Third, there may be concerns regarding the construct validity of the TEPS. The TEPS is purported to evaluate consummatory and anticipatory pleasure separately. Both subscales rely on what the field of affective science terms a “hypothetical” self-report format [86], where scenarios are presented and individuals are asked to report how they would feel if in that hypothetical

Table 2 Summary of studies using the Temporal Experience of Pleasure Scale in schizophrenia and control samples

Citation	Participants	Anticipatory pleasure	Consummatory pleasure	Symptom correlations
Gard et al., 2007 [9]	50 SZ, 1 SA, 50 CN	ANT: SZ < CN	CON: SZ = CN	Greater anticipatory pleasure associated with greater BAS total score, reward responsiveness, drive, lower SANS anhedonia, higher social and family role functioning, lower PAS physical and SAS social anhedonia, greater consummatory pleasure related to lower physical anhedonia.
Favrod et al., 2009 [67]	21 SZ, 82 CN	ANT: SZ < CN	CON: SZ = CN	Greater anticipatory pleasure associated with lower SANS anhedonia, avolition
Wynn et al., 2010 [51]	34 SZ, 36 CN	ANT: SZ < CN	CON: SZ = CN	Higher consummatory scores associated with higher valence ratings for pleasant stimuli
Strauss et al., 2011 [80]	86 SZ, 59 CN	ANT: SZ = CN	CON: SZ < CN	Greater anticipatory pleasure associated with greater BAS total and reward responsiveness, lower Chapman physical, social anhedonia, lower total BPRS positive symptoms, BPRS total symptoms. Greater consummatory pleasure associated with higher BAS total and reward responsiveness, lower Chapman physical anhedonia, BPRS total symptoms.
Cassidy et al., 2012 [76]	91 SZ, 91 CN	ANT: SZ = CN	CON: SZ = CN; CON: SZ with comorbid cannabis-use disorder < CN	None
Lee et al., 2012 [83]	14 SZ, 16 CN	ANT: SZ = CN	CON: SZ = CN	None
Mann et al., 2013 [73]	54 SZ, 39 CN	ANT: SZ < CN	CON: SZ < CN	None
Strauss et al., 2013 [81]	25 SZ, 21 CN	ANT: SZ = CN	CON: SZ < CN	None
Barch et al., 2014 [66]	59 SZ, 39 CN	ANT: SZ < CN	CON: SZ = CN	None
Kring et al., 2014 [69]	16 SZ, 8 SA, 28 CN	ANT: SZ < CN	CON: SZ = CN	None
Mote et al., 2014 [120]	88 FEP, 66 CN	ANT: FEP < CN	CON: FEP = CN	Greater anticipatory pleasure associated with lower BPRS negative symptoms, lower SANS blunted affect. Greater consummatory pleasure associated with lower BPRS negative symptoms, depression, SANS total and alogia.
Schlosser et al., 2014 [79]	234 CHR, 60 FEP, 78 SZ, 29 HC	ANT: CHR < HC, FEP, SZ; SZ = CN	CON: CHR < HC, FEP, SZ; SZ = CN ;	Greater anticipatory pleasure related to greater BAS behavioral inhibition, reward responsivity; greater consummatory pleasure related to greater BAS reward responsivity
Tso et al., 2014 [74]	39 SZ, 24 BP, 36 CN	ANT: SZ < BP, CN	CON: SZ < BP, CN	Greater anticipatory pleasure related to lower SANS anhedonia, Chapman physical and social anhedonia, greater BAS reward responsiveness, drive, and funseeking;

Table 2 (continued)

Citation	Participants	Anticipatory pleasure	Consummatory pleasure	Symptom correlations
				greater consummatory pleasure related to greater Chapman physical and social anhedonia, BAS reward responsiveness, drive, and funseeking
Docherty et al., 2015 [121]	33 CHR, 25 CN	ANT: CHR = CN	CON: CHR > CN	None
Edwards et al., 2015 [77]	53 SZ, 52 CN	ANT: SZ = CN	CON: SZ < CN	None
Fortunati et al., 2015 [68]	53 SZ, 46 CN	ANT: SZ < CN	CON: SZ = CN	Greater anticipatory pleasure associated with lower PANSS general, negative, and total scores, higher PSP score, lower FBF score. Greater consummatory pleasure associated with lower PANSS total and negative scores.
Li et al., 2015 [70]	346 SZ, 176 MDD, 268 CN	ANT: SZ < CN	CON: SZ < CN	Greater consummatory pleasure related to elevated PANSS total scores and PANSS negative score
Li et al., 2015 [71]	4 samples: 1) 364 SZ, 114 CN; 2) 75 FEP, 78 CN; 3) 210 SPD (105 positive SPD, 105 negative), 103 CN; 4) 45 CHR, 45 SZ, 45 CN	Chronic SZ: Abstract ANT: SZ < CN ; FEP: Abstract ANT: SZ < CN ; SPD (Neg and Pos): Abstract ANT: Neg SPD < CN,, Concrete ANT: Pos SPD > CN; CHR: Abstract ANT: CHR < CN, CHR > SZ	Chronic SZ: Abstract Con: SZ < CN; SPD: Abstract CON, Neg SPD < CN, Concrete CON, Pos SPD > Cn; CHR: Abstract CON: SZ < CHR, CN	Greater consummatory and anticipatory pleasure related to greater positive SPQ schizotypy. Lower consummatory and anticipatory pleasure related to greater negative SPQ schizotypy. PANSS negative symptoms related to abstract anticipatory and consummatory pleasure. Longer illness duration correlated with lower anticipatory abstract and concrete pleasure, concrete consummatory pleasure.
Lui et al., 2015 [72]	27 FEP SZ, 26 CN	Abstract ANT: SZ < CN; Contextual ANT: SZ < CN	Abstract and Contextual CON: SZ = CN	VFT Verbal Fluency predicted abstract anticipatory scores
Makowski et al., 2015 [78]	15 SZ, 15 CN	ANT: SZ = CN	CON: SZ = CN	High social reward associated with elevated consummatory and anticipatory pleasure
Mucci et al., 2015 [39]	28 SZ, 22 CN	ANT: SZ = CN	CON: SZ = CN	None
Strauss et al., 2015 [82]	28 SZ, 25 CN	ANT: SZ = CN	CON: SZ < CN	None
Wang et al., 2015 [84]	40 SZ, 29 CN	ANT: SZ = CN	CON: SZ = CN	None

SZ schizophrenia, *CN* control, *ANT* TEPS anticipatory subscale, *CON* TEPS consummatory subscale, *FEP* first-episode patients, *CHR* clinical high risk, *SA* schizoaffective, *SPD* schizotypal personality disorder, *MDD* major depression disorder, *BP* bipolar disorder, *BAS* behavioral activation scale, *PANSS* Positive and Negative Syndrome Scale, *BPRS* Brief Psychiatric Rating Scale, *SANS* Scale for the Assessment of Negative Symptoms, *PSP* Personal and Social Performance Scale, *FBF* Frankfurter Beschwerde-Frageboden Scale, *VFT* verbal fluency test

situation. Hypothetical reports do not rely on experiential emotion knowledge (i.e., direct access to feelings), but rather semantic emotion knowledge (i.e., beliefs about how certain situations would make one feel or how one generally feels). To validly measure consummatory pleasure, scales need to tap into experiential emotion knowledge. By the very nature of its format (i.e., a hypothetical self-report), the TEPS cannot measure consummatory pleasure. To do so, a measure would need to ask participants how they feel in-the-moment when directly exposed to a situation. Therefore, it may be no surprise that many studies fail to replicate the original anticipatory-consummatory differential deficit that was observed in Gard et al. [9]. The anticipatory and consummatory subscales both rely on the same sources of emotion knowledge (i.e., semantic emotion knowledge) and may therefore measure the same underlying construct (i.e., beliefs about how certain situations should make one feel). Newer scales, which have been created in the same format as the TEPS (e.g., The Anticipatory and Consummatory Interpersonal Pleasure Scale (ACIPS: [87]) would also be prone to the same limitations.

A limited number of behavioral paradigms have also begun to examine anticipatory affect and affective forecasting. One study used the Components of Pleasure Task (COP: [77]) to measure anticipatory and consummatory emotion. In this task, participants were directed to rate positive, negative, and neutral stimuli on valence and arousal, and then were trained to associate a subset of the pictures with neutral shape cues. After completing the learning phase, participants were asked to rate their experience of pleasure to the cue itself (anticipatory affect). Results found no significant differences between anticipatory and overall consummatory ratings, although individuals with schizophrenia rated physical pleasant stimuli as significantly less pleasant than controls [77]. Another study focused on affective forecasting in social situations. Engel et al. [88] used the "Cyberball" paradigm [89] to determine if individuals with schizophrenia make errors in prospecting affective experience in social conditions. The Cyberball paradigm involves telling participants that they will be playing an online ball-catching game with two other participants. The authors included two conditions. In the first condition (inclusion), participants were thrown the ball at a rate of 1/3 of the total number of throws. In the second condition (exclusion), participants were not thrown the ball at all. As the researchers were wary of prospections influencing experience (as shown in other studies: [90]), they included an anticipation group and an experience group to directly examine this possibility. The anticipation group rated how positive and negative they expected to feel if included or excluded but were then told there were technical difficulties and so could not complete the Cyberball task. The experience group did not fill out the expected emotion questionnaire and instead completed inclusion and exclusion trials of the task. Their emotions were assessed after task completion. Results of this study indicate that participants with schizophrenia experienced emotions in general with a similar intensity to CN, but anticipated negative emotions more intensely. Therefore, contrary to other studies indicating an anticipation deficit [3, 9, 75, 91], they saw intact anticipation of future positive emotion, but elevated anticipation of negative emotion.

Three studies have examined prospection in schizophrenia. Raffard et al. [92] had participants make prospections while viewing positive and negative pictures and found that people with schizophrenia reported less self-referential, other-referential, and sensory experience than controls. Raters also judged patients' prospections to be less specific. D' Argembeau et al. [93] presented participants with cues representing non-specific situations, specific situations, and general feeling states and asked them to generate both prospections and memories. Raters judged the prospections and memories of people with schizophrenia to be less specific than controls, and the ratio of specific prospections to specific memories was reduced in schizophrenia indicating a weaker link between episodic memory and prospection. Painter and Kring [94] had participants complete a prospection task that was proceeded by a memory task or a control task to determine if episodic memory influenced prospection for positive, negative, and neutral cues. Individuals with schizophrenia were less likely to reference memories from the past during prospections, which were less detailed than controls. Additionally, patients reported comparable positive emotion to controls following the memory task, but less positive emotion than controls following the control task. Collectively, findings from these studies indicate that schizophrenia patients have deficits in generating clear and detailed prospections and suggest that episodic memory deficits contribute to problems with generating future simulations; however, when specifically cued to recall episodic memories, future simulations are more likely to produce potent anticipatory affect. Thus, retrieval deficits and failure to implement strategies to boost prospection may contribute to reduced anticipatory pleasure in schizophrenia.

Potential Mechanisms Underlying Affective Forecasting and Anticipatory Affect Impairments

Assuming that affective forecasting and anticipatory affect deficits are present in schizophrenia, the affective science literature points to several potential mechanisms. First, when people mentally simulate future events, they use their in-the-moment hedonic reactions during those simulations to predict how they might actually feel if that event were to come to pass. The ventromedial prefrontal cortex is critically involved with these "pre-feelings" that result from simulations; however, structures activated by simulations that generate positive and negative emotions may differ. For example, simulations that engender positive emotion activate anterior regions of the VS and the nucleus accumbens, whereas simulations that generate negative emotion activate posterior portions of the VS and amygdala [95, 96]. Subcortical structures, such as the VS and nucleus accumbens, are impaired in schizophrenia and associated with reduced neural response to reward predictive cues [26, 29, 32]; however, amygdala response appears intact in response to negative stimuli [43]. Such findings suggest that individuals with schizophrenia might be expected to not experience intense positive emotion during mental simulations (i.e., pre-feelings/anticipatory affect), but experience normal or exaggerated negative emotion during simulations. As reviewed above, there is some support for this pattern of deficits, but it is inconsistent.

Second, individuals base their affective forecasts (i.e., predictions or beliefs of how good they will feel when an event occurs) on different sources of emotion knowledge than their in-the-moment reports [86]. Specifically, in-the-moment reports directly access feelings and rely on experiential emotion knowledge, without being influenced by semantic or episodic memory, whereas prospective reports of future pleasure rely on semantic emotion knowledge (i.e., beliefs about how one

generally feels or how certain situations should make one feel). This is why reports of future pleasure are often overestimates of what comes to pass—individuals access different sources of emotion knowledge when making prospective and in-the-moment pleasure reports. Strauss and Gold [4] proposed that individuals with schizophrenia have problems with affective forecasting that can be understood as "low pleasure beliefs" that impact all types of emotional report that require access to non-current feelings (i.e., trait, retrospective, hypothetical). Cognitive deficits may contribute to these low pleasure beliefs, such that impairments in learning, working memory, and long-term memory prevent intact in-the-moment hedonic experiences from being encoded, where they could be used as counter-evidence against the belief that certain situations or life in general is not pleasurable. Thus, cognitive impairments may maintain inaccurate representations that fuel low pleasure beliefs and color affective forecasts to predict limited pleasure.

However, several other factors may also influence affective forecasting deficits. Accurate affective forecasting requires two conditions to be met: (1) the simulation at the time of the forecast must influence hedonic experience in the same manner as the perception of the event at the time of the forecasted event and (2) contextual factors at the time of the forecast must influence hedonic experience in the same manner as the contextual factors at the time of the forecasted event [52]. In healthy individuals, these conditions are often not met during everyday life, resulting in mental simulations that are inaccurate and an overestimation of the intensity or duration of emotion that is actually experienced when the forecasted event comes to pass. Gilbert and Wilson [52] propose four errors in prospection that lead to overestimation when the aforementioned pre-requisite conditions are violated: (1) simulations are unrepresentative; (2) simulations are essentialized; (3) simulations are abbreviated; (4) simulations are decontextualized. These errors in prospection have not been systematically studied in schizophrenia. In the sections that follow, we review each error in hopes of inspiring future research in this area. We propose that cognitive and motivational impairments may prevent these normative errors in prospection from functioning normally paradoxically making individuals with schizophrenia have more accurate future simulations than controls (i.e., less overestimation of future pleasure).

Prospection Error 1: Simulations Are Unrepresentative

To estimate how we might feel in the future, we often draw upon experiences from the past. Memories are therefore a key component of future simulations. However, if memories are not an accurate representation of the past, simulations will also be unrepresentative. Research suggests that it is typical for healthy individuals to use unrepresentative memories when formulating simulations. In particular, unrepresentative memories are heavily influenced by peak and recency effects, which cause individuals to construct future simulations based on their best day, worst day, and "yesterday" (i.e., recent moments), rather than their most typical experiences [97–99]. The extent to which retrieval is biased by peak and recency effects therefore plays an important role in determining overestimation.

It has yet to be determined whether episodic memory deficits cause peak and recency effects to have a reduced influence on future simulations in schizophrenia. Recency may not be expected to play a role, as serial list learning studies have demonstrated intact recency recall in schizophrenia [100, 101]; however, episodic memory is impaired in schizophrenia, with aberrant activation of prefrontal and medial temporal lobe regions predicting poor encoding and retrieval [102]. Furthermore, some studies on emotional memory point to a long-term memory deficit in schizophrenia that is specific to pleasant stimuli, even in the context of intact in-the-moment hedonic response [103, 104]. Impairments in long-term memory for pleasant stimuli are thought to reflect deficient long-term potentiation and consolidation processes [105]. Such impairments could be expected to lead patients to be less likely to draw upon unrepresentative peak intensity moments than controls, thereby making their simulations of future positive experiences paradoxically more accurate (i.e., less overestimation).

Prospection Error 2: Simulations Are Essentialized

The predicted hedonic experience of a future event is a weighted average of two factors: (1) the extremely positive or negative essential features that define the experience and (2) mildly positive or negative inessential features that accompany the essential features of the experience [52]. When simulating the future, healthy individuals tend to omit inessential features, therefore predicting that good events will be better and bad events worse than they actually are [106]. For example, when simulating a future vacation, individuals often base their hedonic prediction on essential features (e.g., eating great food, exciting new sites, aesthetic beauty) and ignore inessential features (e.g., waiting in lines, traffic, traveling between locations) that lower the overall net hedonic value of an experience in the moment. Furthermore, individuals are more likely to omit inessential features when an event is temporally distant, making overestimation more likely to occur for events farther in the future. Overestimation effects tend to reduce as an event becomes more temporally proximal. Thus, whether an individual is simulating an event that is distal/proximal and whether their simulations are detailed enough to contain essential and inessential features may dictate the magnitude of overestimation [107].

It is possible that certain cognitive impairments may cause individuals with schizophrenia to generate future simulations that are devoid of both essential and inessential details. Deficits in prospection have been demonstrated in several studies now, where future simulations have been found to be less clear and specific [92, 93]. Impairments in episodic memory may influence the extent to which patients formulate detailed simulations, making individuals with schizophrenia less likely rely on memories while generating representations of future events.

Prospection Error 3: Simulations Are Abbreviated

Mental simulations of the future tend to be brief, taking far less time than the actual events themselves would require to unfold in real life [52]. However, this efficiency comes at a cost—it results in simulations that are so abbreviated that they contain only a few key aspects of the future event. Most simulations represent early portions of the event, where hedonic reactions tend to be strongest, and fail to represent later moments [108, 109] As a result, simulations often fail to take into account adaptation and are overestimations of most events that come to pass because emotional reactions tend to dissipate over time.

Several lines of research indicate that people with schizophrenia have deficits in generating and updating mental representations of value, which could make simulations less potent at inducing positive affect (see [17 2014]). For example, deficits are noted on delay discounting tasks, reversal learning paradigms that require updating, and simple preference tasks without a learning component [110–112]. Whether problems with value representation are linked to low positive affect during simulations is unclear; however, neuroimaging and psychophysiological studies indicate that people with schizophrenia have a deficit in maintaining positive experiences when not directly exposed to a stimulus [8•, 113]. It is possible that impairments in generating, updating, and maintaining value representations may cause future simulations to not include salient features or not last long enough to generate a fully intense positive experience. It is unclear whether such deficits might reflect a broader impairment in working memory, or a deficit that is specific to the representation of value [114].

Prospection Error 4: Simulations Are Decontextualized

For simulations to be accurate, contextual factors must influence the hedonic state at the time of the simulation similarly to the hedonic state when the predicted event is actually experienced. Accurate simulations typically only occur when the simulation and event are contiguous, increasing the probability of contextual similarity [52]. Most simulations are inaccurate because contextual factors tend to change very frequently for most healthy individuals who engage in a range of activities, interact with many different individuals, and traverse a variety of settings from day to day [115]. Thus, a normal amount of behavioral and environmental variability may contribute to affective overestimation, due to a mismatch between contexts at the time of simulations and events.

Several factors may make individuals with schizophrenia have fewer contextual changes than controls during everyday life. For example, many individuals with schizophrenia have more limited financial resources, resulting in a daily routine that is less contextually variable in terms of exposure to recreational activities, diverse foods, interactions with different people, and changes in settings (e.g., home, work, commuting, others' homes). Negative symptoms (e.g., avolition and asociality) may also reduce motivation and limit behavioral repertoires to engage in a variety of activities [116]. Positive symptoms (e.g., persecutory delusions, auditory hallucinations) also sometimes lead to behavioral withdrawal, in an effort to combat distress via avoidance, potentially restricting contextual range. Perhaps paradoxically, symptoms may therefore result in more accurate simulations of future positive emotion because patients have more contextual consistency and therefore less overestimation. Alternatively, people with schizophrenia also have deficits in representing and maintaining context information in working memory [117]. A failure to process context at the time of the simulation or event itself may lead to reduced overestimation.

Conclusions and Future Directions

Anticipatory pleasure involves several inter-related constructs that rely on overlapping cognitive and neural mechanisms. These include the following: (1) associative conditioning, (2) prospection, (3) anticipatory affect, and (4) affective forecasting. The model presented in Fig. 1 presents hypothesized interactions for these processes that appear to contribute to anticipatory pleasure deficits in schizophrenia.

The literature to date provides mixed evidence for abnormalities across these constructs in people with schizophrenia. The most consistently reported finding is a deficit in associative conditioning on the MID task, where schizophrenia patients evidence reduced activation of the VS in response to cues that predict potential reward. Some have interpreted this evidence as support for a deficit in "anticipatory affect" (i.e., experiencing positive emotion during future simulations); however, studies have not directly examined whether self-reported pleasure during different task phases predicts neural activation, as has been done in healthy individuals [22]. As such, it is unclear whether MID deficits reflect problems with learning, anticipatory affect, or both. Regardless of mechanism, this impairment is consistently associated with greater severity of negative symptoms.

Deficits in prospection have also been replicated in several studies, which report that schizophrenia patients have less

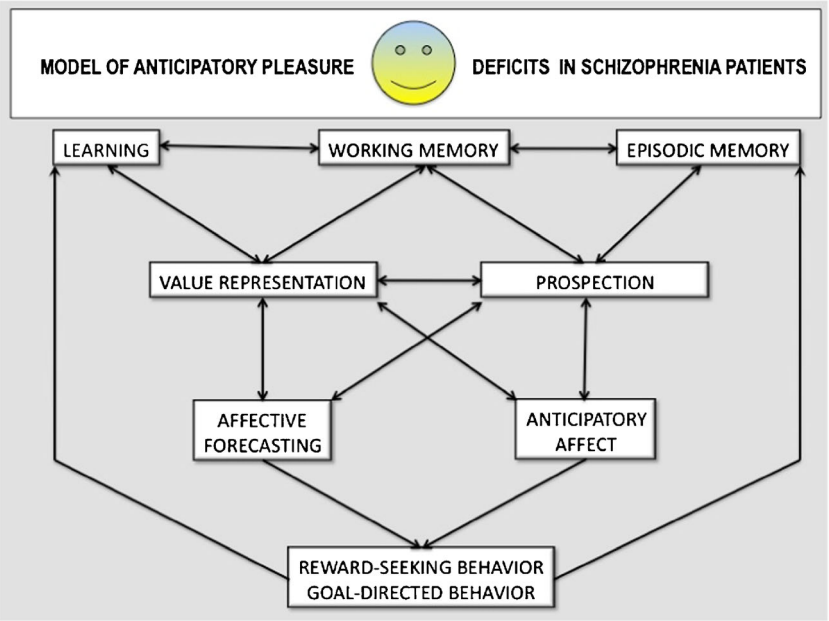

Fig. 1 Model of how anticipatory pleasure deficits lead to decreased motivated behavior in schizophrenia. Note: basic cognitive impairments in learning, working memory, and episodic memory impact the ability to generate mental representations of reward value and rich/detailed prospection's of the future. These deficits in turn impact anticipatory affect (i.e., experiencing positive emotion while simulating the future) and affective forecasting (i.e., accurately predicting future positive emotions) that lead to reduced goal-directed and reward-seeking behavior

clear and detailed future simulations than controls. Impairments in episodic memory may underlie these deficits. However, it is unclear whether problems with prospection reflect a "cold" cognitive deficit that detrimentally impacts all simulations, or a problem that is specific to simulating potentially rewarding situations. Future studies are needed to explore this question, as well as the components of memory and neural substrates that impact prospection since prior studies were behavioral.

Studies tapping into affective forecasting have yielded the most mixed findings. This is to some extent due to differences in methods used across studies (e.g., EMA vs questionnaire or laboratory-based self-report), potential issues with the construct validity of some measures (e.g., TEPS), and the lack of clear focus on mechanisms underlying overestimation. The affective science literature has validated a series of paradigms that examine affective forecasting and demonstrated how the four errors in prospection (unrepresentative, essentialized, abbreviated, decontextualized) lead healthy individuals to overestimation future positive and negative emotions (see [52]). These paradigms have not been applied to study anticipatory pleasure in schizophrenia. Future studies are needed to test the conjectures posited here, which linked deficits known to exist in schizophrenia with mechanisms that might impact each error. We suspect that impairments in cognition and motivation paradoxically make individuals with schizophrenia more accurate in their simulations, and therefore less likely to overestimate future pleasure.

There is also a growing literature pointing to intact or exaggerated overestimation of negative emotion in schizophrenia. The reasons for this dissociation are unclear at present. However, the affective neuroscience literature provides important leads for future studies, implicating distinct neural circuitry in the anticipation of positive and negative emotion. Although too few studies have been published to draw firm conclusions, it is possible that the cognitive (e.g., representation of losses, learning from negative feedback, memory for unpleasant stimuli) and neural mechanisms (e.g., amygdala) underlying the anticipation of negative emotion are intact in schizophrenia, whereas cognitive (e.g., generating, updating, and maintaining reward representations, memory for rewards, learning from positive feedback) and neural (e.g., VS activation) mechanisms supporting anticipatory pleasure are impaired. It is also possible that anticipatory negative affect may play an even bigger role in motivational problems than anticipatory pleasure, which appears to be less consistently impaired in schizophrenia. We suspect that negative emotion abnormalities, which occur across all reporting timeframes (prospective, current, retrospective), may lower the overall net hedonic value of simulations and experiences, even those that are intensely positive. Such deficits may reflect a fundamental deficit in emotion regulation (i.e., using strategies to decrease negative emotion) [81, 82, 118] that lead negative emotion to go unchecked and bleed over into most everyday situations, even those that are more positive or neutral.

Compliance with Ethical Standards

Conflict of Interest Ms. Katherine H. Frost and Dr. Gregory P. Strauss declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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